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METHOD AND DEVICE FOR EFFECTING A COMPUTER-AIDED ESTIMATION OF THE MASS OF A VEHICLE, PARTICULARLY OF A COMMERCIAL VEHICLE

Background Information

The present invention relates to a method and a device for effecting a computer-aided estimation of the mass of a vehicle, particularly of a commercial vehicle, as recited in Claim 1 and Claim 11.

In electronic vehicle systems such as electronic stability programs (ESP) for regulating driveability in the extreme range from the standpoint of driving dynamics, or in electronically regulated brake systems (EBS) for commercial vehicles, a value is generally needed for the mass of the vehicle. Since as a rule, no sensors are present for ascertaining the mass, the vehicle mass must be calculated or estimated by suitable algorithms.

DE 42 28 413 Al describes a method for determining the vehicle mass, in which two longitudinal vehicle accelerations at at least two different points of time and the propulsive powers existing at these points of time are measured. The vehicle mass is then determined from the difference between the propulsive powers and the difference between the longitudinal accelerations.

According to DE 198 02 630 Al, to determine the vehicle mass, the propulsive power and the corresponding longitudinal vehicle acceleration are measured at points of time continually following each other with constant time intervals.

The U.S. Patent 6,347,269 B1 proposes ascertaining the vehicle mass on the basis of the propulsive powers, the running

resistances and the vehicle acceleration, the influence of the roadway inclination being eliminated by a high-pass filter.

According to WO 00/11439 A1, to ascertain the vehicle mass, at least two time-staggered measurements are determined, including one tractive-force variable and one movement variable of the vehicle, one of the two measurements being carried out during a phase free of tractive force, and the other during a tractive-force phase.

From the generic German Patent DE 101 44 699 A1, a method is known which is based on the equilibrium relationship between the motive force on one hand, and the accelerative force and the climbing resistance. This equilibrium relationship reads:

$$F = m \cdot (a + g \cdot \sin\alpha) \qquad (1)$$

where

F = motive force

a = time derivation of the longitudinal vehicle velocity

α = gradient angle of the roadway

g = gravitational acceleration

m = vehicle mass

In equation (1), the accelerative force is represented by the product m•a, and the climbing resistance by the product $m \cdot g \cdot \sin\alpha$. To calculate mass m of the vehicle, equation (1) is therefore solved for m, and the instantaneous values for F, a and α are determined from measured quantities. Since gradient angle α of the roadway being traveled at any one time is not known, as a rule it is estimated with the aid of a computer during coupling phases or during phases without or with very low motive force, or is disregarded altogether. When using converter clutches or powershift transmissions, however, such freewheeling phases are no longer available, so that a

sufficiently accurate estimation of the vehicle mass is difficult.

Therefore, the object of the present invention is to further develop a method for effecting a computer-aided estimation of mass m of a vehicle of the type mentioned at the outset in such a way that the above-indicated disadvantages are avoided. The intention is also to make available a device for the application of the method.

This objective is achieved by the features of Claim 1 and Claim 11.

The invention is based on the concept of evaluating changes in the operating state of the vehicle over time t for estimating the vehicle mass. When a vehicle is traveling along any route, gradient angle α of the roadway is a function of time t. If one differentiates equation (1) with respect to time t, the following equation results:

$$\dot{F} = m \cdot (\dot{a} + g \cdot \dot{\alpha} \cdot \cos\alpha) \qquad (2)$$

Assuming the change in gradient angle $\alpha(t)$ is very small in time interval dt considered, the influence of gradient angle $\alpha(t)$ is to be minimized or eliminated. Then $\dot{\alpha} = d\alpha/dt \approx 0$ applies, and equation (2) reads as follows:

$$\dot{F} = m \cdot \dot{a} \qquad (3)$$

Due to the time derivation of equation (2), it was therefore possible to advantageously eliminate the influence of gradient angle α, assumed to be constant for a time, in equation (3), so that gradient angle α would not have to be estimated, calculated or measured by a cost-creating sensor.

Equation (3) solved for estimated value $\hat{m}$ of the vehicle mass then reads:

$$\hat{m} = \frac{\dot{F}}{\dot{a}} \qquad (4)$$

Equation (4) thus forms the estimate equation for mass m of the vehicle. The estimate equation is preferably calculated continuously, e.g., by recursive methods. The recursive algorithms used may contain so-called forget factors with which the behavior of the algorithm may be adjusted. The forget factors are adjusted in the direction of faster convergence in suitable situations, e.g., during longer stand-still times in which mass m of the vehicle could change.

To estimate m according to equation (4), the variables F and a or $\dot{F}$=dF/dt and $\dot{a}$=da/dt must be determined.

Motive force F includes, inter alia, the known running resistance and drive resistance developing, for example, due to friction losses in the engine and transmission, etc., and/or sustained braking forces:

$$F = \frac{M \cdot \omega - \Theta \cdot \dot{\omega}}{v} \cdot \eta - 1/2 p \cdot c_w \cdot A \cdot v^2 \qquad (5)$$

where

M = Engine torque including friction torque

ω = Engine speed

v = Vehicle velocity

A = Frontal area of the vehicle

η = Drive-train efficiency

Θ = Moment of inertia of the engine

p = Density of the air

c_W = Drag coefficient

The quantities in equation (5) therefore include vehicle-specific quantities such as moment of inertia of the engine Θ,

drag coefficient c_w, frontal area A and drive-train efficiency η of the vehicle. The vehicle-specific quantities are preferably stored in a memory unit of a control unit of the vehicle. Furthermore, equation (5) includes quantities concerning the instantaneous driving conditions of the vehicle such as engine torque M, engine speed ω, vehicle velocity v and density p of the ambient air that are measurable or are constantly able to be fetched in the control unit of the vehicle. From the indicated data or quantities, a calculating unit, preferably the control unit of the vehicle itself, is able to calculate motive force F and acceleration a.

The term $\dot{a}$ in the denominator of equation (4) is the derivation of vehicle acceleration a with respect to time t and is known as jolt. Therefore, mass m can only be estimated during suitable phases in which da/dt and dF/dt is not equal to 0.

The control unit differentiates quantities F and a using suitable methods such as the two-point differentiation method or a state-variable filter, the derivation preferably being carried out over longer time intervals. To improve the accuracy of the estimation, the differentiated quantities may subsequently be filtered. Preferably using a least-square algorithm, estimated value $\widehat{m}$ for the vehicle mass is then calculated as follows:

$$\widehat{m} = \frac{\sum_{i=1}^{N} \dot{F}_i \cdot \ddot{v}_i}{\sum_{i=1}^{N} \ddot{v}_i \cdot \ddot{v}_i} \qquad (6)$$

with i as subscript for the i-th measured value. The measured quantities such as vehicle velocity v are suitably weighted, for example, the weighting being carried out as a function of the accuracy of the measured quantities. Moreover, the measured quantities concerning the instantaneous driving

conditions of the vehicle may be filtered as a function of the signal quality. The quantities concerning the instantaneous driving conditions of the vehicle may furthermore be measured repeatedly, and the measurements weighted differently.

Depending on the quality of the measured quantities for vehicle velocity v and force F, instead of calculating $\hat{m}$, it may be more favorable to calculate the reciprocal value $1 / \hat{m}$. Alternatively, both a value for $\hat{m}$ and reciprocal value $1/\hat{m}$ could be calculated, and a weighted average value formed.

In addition to the method, the present invention also includes a device for effecting a computer-aided estimation of the mass of a vehicle, especially of a commercial vehicle. This device includes a calculating unit for calculating the mass of the vehicle and/or the reciprocal value of the mass from the equilibrium relationship between motive force F and the running resistances, into which mass m and gradient angle α of the roadway are entered as calculation quantities, after a computer-aided differentiation of the equilibrium relationship with respect to time, assuming gradient angle α is constant. This calculating unit is preferably integrated into the control unit of the vehicle.